U.S. AIR FORCE (USAF) AIRFIELD PAVEMENT EVALUATION PROGRAM

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ABSTRACT

The U.S. Air Force (USAF) Airfield Pavement Evaluation (APE) Program obtains, compiles, analyzes, and reports pavement strength, condition, and performance data on all airfields with present or potential Air Force missions. The program is executed by the APE team based at Headquarters, Air Force Civil Engineer Support Agency (HQ AFCESA), Tyndall AFB, Florida. In addition to structural evaluations, the AFCESA pavement section performs runway friction characteristics surveys, monitors pavement condition inspections, performs pavement research, and develops criteria, standards, and policy. The AFCESA pavement section consists of eight military members, two civilian members, and three contractors. This paper will discuss the approach and methodology used by the team to accomplish the structural airfield pavement evaluation mission.

AFCESA's APE team uses a multi-faceted approach to evaluate the structural capacity of airfields. A combination of nondestructive, semi-destructive, laboratory, and visual methods are used to gain a comprehensive view of an airfield's remaining life as well as past performance. Non-destructive methods are primarily accomplished using a Dynatest 8081 Heavy Weight Deflectometer (HWD). Semi-destructive methods include pavement sampling via various size core samples. After the core samples have been extracted, underlying soils are tested in-situ via Electronic Cone Penetrometer (ECP) or Dynamic Cone Penetrometer (DCP) tests. Soil samples are then taken for laboratory classification and analysis. Portland Cement Concrete (PCC) cores are tested via direct and indirect methods. Finally, the entire surface of the pavement system is visually surveyed to determine pavement structural deficiencies, augment the various materials testing performed, adjust allowable aircraft weights, and to determine a Pavement Condition Index (PCI). With its multi-faceted approach, the US Air Force's Airfield Pavement Evaluation (APE) team supports ongoing military operations around the globe.

INTRODUCTION

Prior to 1970, the U.S. Army Corps of Engineers (USACE) performed airfield pavement evaluations for the U. S. Air Force (USAF). USAF experience in Vietnam highlighted the need for a well-trained, well-equipped in-house team dedicated to rapidly responding to Air Force needs and requirements. As a result, the Airfield Pavement Evaluation (APE) team was established in 1970 at Wright-Patterson AFB, OH as a primary mission of the Air Force Civil Engineering Center (CEC), now the Air Force Civil Engineer Support Agency (AFCESA). The CEC moved to Tyndall AFB, FL in 1972. Although the organization's name has changed several times over the years, the pavement evaluation mission remains basically the same. Pavement responsibilities were increased in 1978 and 1979 when criteria, standards and policy functions at the Pentagon and Bolling AFB were consolidated at AFCESA.

The APE team concept was developed to provide a uniform airfield pavement evaluation for USAF bases during peacetime and a contingency evaluation capability in time of war or conflict. Since its inception, the team has accomplished 584 structural pavement evaluations and 434 surface friction evaluations. It has been involved in Operations DESERT STORM, JOINT ENDEAVOR, JOINT GUARD, ALLIED FORCE, NOBLE ANVIL, and ENDURING FREEDOM, as well as supporting numerous exercises and aircraft deployments worldwide. The team is currently composed of eight military, two Federal civilians, and three contract personnel. It is the only active duty military organization providing full spectrum structural and friction airfield evaluations for the United States.

The APE team's evaluation methodology also makes it unique (Reference 1). The cyclical, multi-pronged approach provides the best data for commanders at all levels. Operational bases are scheduled for a structural evaluation on an 8 to 10 year cycle. These structural evaluations include pavement testing, visual inspection, material classification, and a pavements record review, as detailed below. Pavement Condition Index (PCI) surveys are scheduled every 3 to 5 years, or as determined by the major command pavement engineer. These surveys are accomplished via contract or by specially-trained Air Force Reserve/Air National Guard teams. The data is then input into the MicroPAVER pavement management system for analysis. A scheduled three-year cycle is also in effect for AFCESA's friction evaluations.

The evaluation process has changed significantly since 1970. Initially, all testing was destructive. Approximately 15-20 3'x 5' pits were opened at critical locations and plate bearing tests performed on rigid pavements and California Bearing Ratio (CBR) tests on flexible pavements. These tests were labor intensive and severely impacted airfield operations. Tests at each location took as long as 8 hours to complete and with repairs, a runway was closed for at least 3 days. A transition to nondestructive (NDT) testing began in the mid 1970s with development of a large vibratory device that generated and captured surface waves for analysis. The equipment was contained in a trailer truck; tests took several hours at a location and was not practical for deployment. The next generation of NDT devices was developed and used in the early 1980's. It also used surface wave technology but dropped a weight to generate the waves and sensors epoxied to the surface to record the data. It was much smaller and more practical but still took considerable time to complete the tests and analysis.

The most revolutionary period in the USAF Airfield Pavement Evaluation Program occurred during the 1985-90 timeframe. During this span, the APE team incorporated a variety of technologies to minimize disruption to airfield operations, enhance ability to respond to contingencies, and reduce analysis/reporting time. Specifically, this was the era when the Falling Weight Deflectometer (FWD) (Reference 4), the airmobile Electronic Cone Penetrometer (ECP), the Dynamic Cone Penetrometer (DCP), and the personal computer were incorporated into APE operations.

Current equipment and software gathers and processes data at rates up to 50 times faster than techniques used prior to 1985 with minimal disruption to the airfield.

STRUCTURAL TESTING

Structural evaluations continue to be the major focus of the APE team. A variety of tools are used to accomplish this mission. They consist of an Electronic Cone Penetrometer (ECP), Automated and Manual Dynamic Cone Penetrometers (DCP), Heavy Weight Deflectometers (HWD), and Pavement Coring Sets. Equipment (tool) packages are assembled to provide the best data for a given location.

Figure 1--Electronic Cone Penetrometer

The first airmobile ECP was brought into APE operations in 1990. The current ECP vehicle (Figure 1) began operations in 1997. Both vehicles were constructed by Vertek Industries, a division of Applied Research Associates (ARA). The current version was designed as a self-contained contingency response vehicle to support the APE team's wartime tasking. The vehicle houses the ECP within an enclosed workspace and has a pavement coring drill mounted on the rear. The shell of the truck collapses, making the unit air transportable aboard a C-130 aircraft. The ECP consists of a cone with two sensors designed to measure tip pressure and sleeve friction. The principle components of the ECP include: a hydraulic ram that presses the cone assembly (Figure 2) into the soil at a constant rate of 0.8 in/sec; a 1.41-inch diameter cone with a 60-degree tip equipped with a load cell to measure the tip resistance to penetration; and a 5.27-inch long sleeve, located just above the cone which slides on the rod and measures the sleeve friction imposed by the surrounding soil. The ECP measures strengths of soil layers beneath the pavement by creating a shear failure of the soils. The results are reported in terms of cone tip and sleeve friction resistance with depth. ECP results can be correlated to soil type and CBR using relationships developed for AFCESA through joint research by the Engineering Research and Development Center at Waterways Experiment Station (ERDC-WES), the USAF Academy, and the Air Force Research Laboratory (AFRL) (References 2 and 3). Porewater pressures can also be tested when required. Interpretation of the tip and sleeve data can yield soil layer thickness in underlying pavement layers as well. Data are then input into the Airfield Pavement Evaluation software developed by ERDC-WES. This software uses WES's empirical design curves in reverse. It enters the curves with layer thickness and strength to produce allowable aircraft gross loads (AGLs), allowable passes, and Pavement Classification Numbers (PCNs).

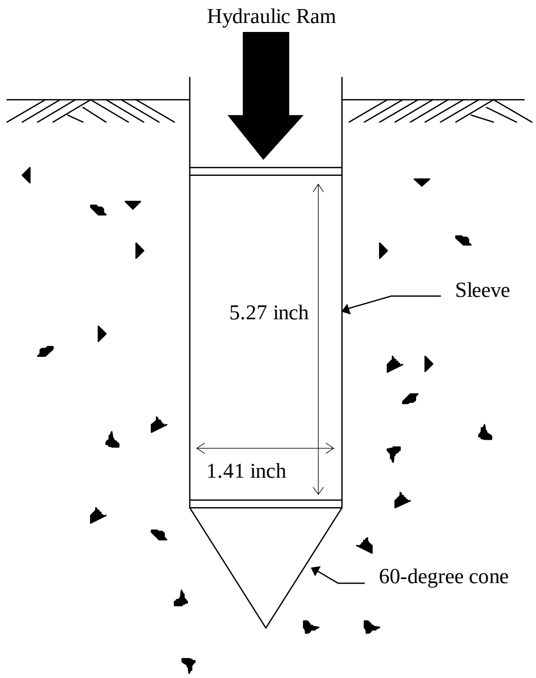

Figure 2--Electronic Cone Penetrometer

Another method of in-situ soil testing is the Dynamic Cone Penetrometer (DCP)(Figure 3). The concept of operations is very similar to that employed while using the ECP. The four main components of the DCP are the cone, rod, anvil, and hammer. The cone is attached to one end of the DCP rod while the anvil and hammer are attached to the other end. Energy is applied to the cone tip through the rod by dropping the 8 kg hammer a distance of 575 mm against the anvil. The diameter of the cone is 4 mm larger than that of the rod to ensure that only tip resistance is measured. By recording the number of hammer blows it takes to advance the cone into the soil, the soil strength is quantified in terms of a DCP index. The DCP index is the ratio of the depth of penetration to the number of blows of the hammer and has been empirically correlated to the California Bearing Ratio (CBR) (References 2 and 3).

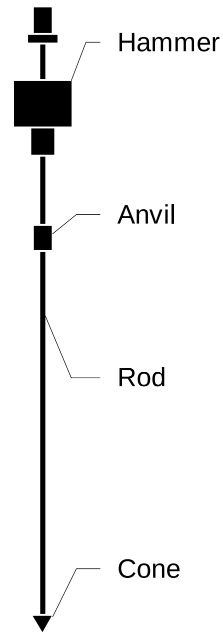

Figure 3--
Dynamic Cone
Penetrometer

The APE Team uses two methods of DCP employment. The first is the manual method. In this method, the hammer is lifted and dropped manually. Penetration and blow count data can be measured and recorded manually. The team also has the option of using the Automated Data Acquisition System (ADAS) developed by the Air Force Research Laboratory (AFRL) which collects and feeds data directly to a laptop computer for analysis. The DCP Index is then derived. The second method of DCP employment is the automated DCP vehicle. This vehicle combines a core drill and an automated DCP into a small contingency package. The automated DCP truck (ADCP), constructed by Vertek Industries, a division of Applied Research Associates (ARA), is the newest contingency response vehicle for AFCESA. In this test, the DCP hammer is dropped automatically by a mechanically driven drop mechanism. The data is then fed to a data acquisition computer and the DCP Index is derived. The data is then input into WES's APE analysis software described above. The ADCP was placed into service in 2001, and has been deployed to Guatemala and in support of Operation ENDURING FREEDOM.

The third tool in the APE team's bag is the Heavy Weight Deflectometer (HWD). The Air Force currently employs two Dynatest 8081 Heavy Weight Deflectometers for nondestructive testing. These trailer-mounted HWDs consist of a weight package imparting an impact load and deflection measurement sensors (Figure 4). The weight package is raised by an electro-hydraulic servo system and released imparting a dynamic load. The load impacts an 11.8-inch diameter circular steel plate encased with a rubber pad. This results in a buffered load pulse of 0.025 to 0.030 seconds in duration. By use of different drop weights and heights, the impact load imparted to the pavement structure can be varied within a range of 6,500 lbs to 54,000 lbs. The deflection measurement package consists of seven velocity transducers in contact with the pavement surface and spaced at 12-inch intervals from the point of impact. An onboard computer records the deflection "basin" and provides the operator instantaneous deflection information. This raw data is automatically stored for analysis. This data is then input into the Layered Elastic Evaluation Program (LEEP) software developed by WES.

The following assumptions (Reference 5) are made when evaluating a pavement using LEEP:

1) the pavement system is a layered continuum;

2) layers extend horizontally to infinity;

3) the bottom layer extends to infinity;

4) layers are linear elastic, isotropic, and homogenous;

5) loads are static and applied as circular areas of uniform pressure; and,

6) layer material is only characterized by the Modulus of Elasticity (E) and Poisson's Ratio (n).

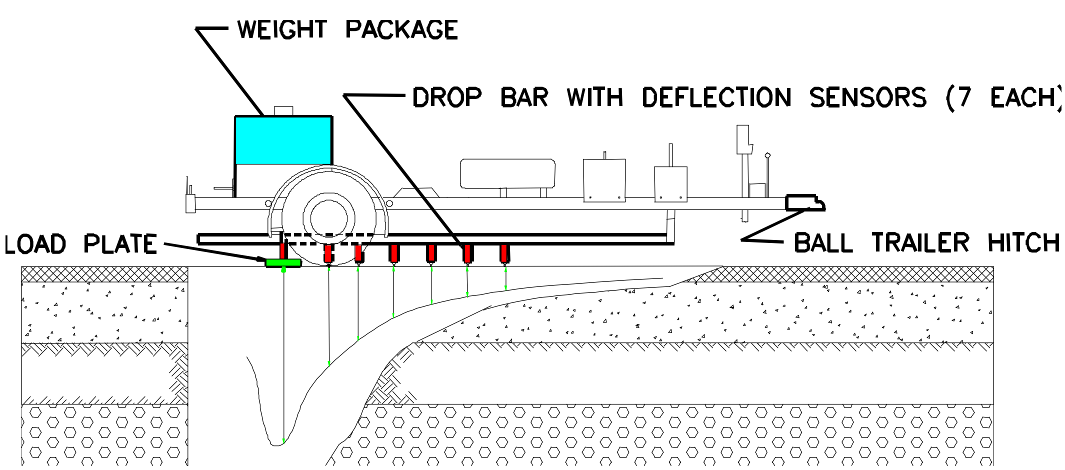

Figure 4--Heavy Weight Deflectometer and Deflection Basin

Although various layered elastic models are available, the WESLEA model (Reference 6) underpins the LEEP evaluation software. WESLEA backcalculates layer moduli values after layer structure and thickness are inputted. After the moduli are calculated, they are inputted into the analysis module WESDEF. WESDEF then calculates allowable aircraft gross loads (AGLs), allowable passes and Pavement Classification Numbers (PCNs).

Finally, the pavement core drill is a vital tool for pavement evaluation for several reasons. First, the cores are used to verify pavement thickness. Second, coring provides access to the underlying pavement layers for sampling and testing with other equipment, such as the ECP or DCP. Lastly, extracted Portland Cement Concrete (PCC) cores are tested to determine flexural strength. Six-inch diameter diamond-tipped coring barrels are used to cut through both asphalt concrete (AC) and PCC pavements. APE team core drills are capable of cutting through pavements to depths of approximately 36 inches. Normally, at least one core is extracted from each airfield feature. Following penetration testing and soil sampling, local airfield maintenance personnel patch the core hole. PCC cores are shipped to AFCESA for flexural strength testing.

VISUAL INSPECTION

While performing the field testing cited above, the APE team also performs a cursory visual survey of all airfield pavements to rate the surface condition of each feature in terms of a Pavement Condition Index (PCI). The APE team does not lay out detailed sample units as prescribed by ASTM. (As previously discussed, detailed PCI surveys occur under a separate effort primarily due to the demands on the team's schedule.) The intent of the visual survey is to group the pavements into three general categories: ADEQUATE (PCI 100-70), DEGRADED (PCI 70-55), and UNSATISFACTORY (PCI 55-0) (Figure 5). A presentation of these Engineering Assessment (EA) ratings provide commanders a visual trigger regarding what level of maintenance and/or repair they should plan. These ratings are a qualitative assessment of the pavement surface condition and should not be confused with the structural capacity of a pavement.

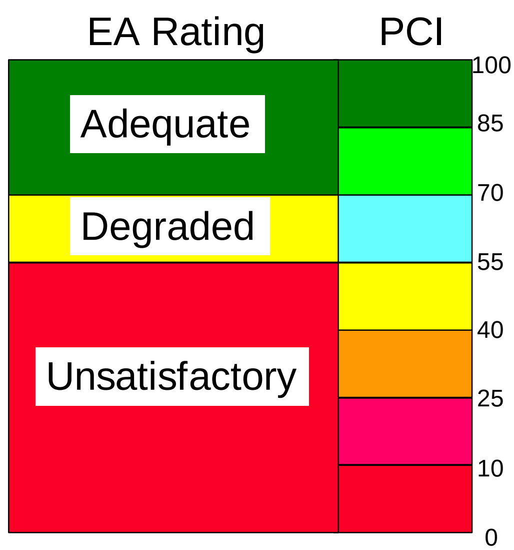

Figure 5--Pavement Surface Condition Rating Scale

It is important to monitor and track the surface condition of pavements to identify pavement problems early and plan appropriate repairs before costly reconstruction is required. A continual evaluation program can also help determine the most cost effective maintenance and repair action. Many pavement owners, such as cities, highway departments, and airports use the PCI scale as a means to program maintenance and repair spending. The owners establish a PCI threshold that triggers maintenance action, a second PCI level that triggers repair, and possibly a third that triggers reconstruction. This is based on the theory that the rate of deterioration of the surface condition increases as the pavement ages. By visualizing surface condition deterioration in this manner, the reader can see that the reported PCI indicates much more than a single number, but identifies the pavement's current stage in its life span. Maintenance activities are generally recommended for the pavements that rate ADEQUATE, where the cost is lower. If the owner waits until the pavement rates DEGRADED, the costs will far exceed routine maintenance, and some heavy repair may be required. This is obviously the more expensive option. Reconstruction is generally the only option for pavements rating UNSATISFACTORY.

Of more direct impact to this structural evaluation, the value of completing the cursory PCI survey is threefold. First, it is a tool that helps identify potential structural problems. Second, for those pavements with PCI ratings lower than 40, reported Allowable Gross Loads (AGLs) are reduced; therefore, to complete the structural analysis it must be determined whether any of the pavement features fall into those categories. Finally, the PCI survey can be used as a gauge to determine if the pavement is approaching the end of its life. If a pavement has a high density of structural distresses in the wheel path, it is reasonable to conclude a substantial portion of the pavement life has been consumed. Conversely, without these structural distresses, the majority of the pavement life likely remains. The cursory survey performed by the AFCESA APE team during structural evaluations is also used to validate the in-depth PCI required every 5 years by AFI 32-1041 "Airfield Pavement Evaluation Program" (Reference 1).

LABORATORY TESTING

In addition to its field capabilities, AFCESA maintains a laboratory for concrete and soil testing. PCC testing is done in one of two ways. Primarily, flexural strengths of the PCC cores are determined by resonant frequency methods. This procedure determines the resonant, or natural, frequency of the concrete following the standard procedure for determining longitudinal resonant frequencies using the impact resonance method (ASTM C215-97). Next, the resonant frequency is correlated to flexural strength. In this method, the PCC core is cleaned and scrubbed with a wire brush to remove any loose material. Any AC overlays and/or stabilized materials that may be attached to the PCC core are removed. The core is placed on a piece of foam rubber or a vibration-free surface and an accelerometer is attached to one end of the core. The opposite end of the core is tapped with a hammer. The accelerometer senses the vibration of the core and a computer records the motion. This motion is analyzed to determine the frequency components of the motion. The frequency with the greatest motion amplitude corresponds to the natural frequency. Once the natural frequency, f_R, is known for a core of length L, the compression wave speed, V_p, can be calculated. Next, the compression wave speed is converted to flexural strength, F, using a correlation determined from a laboratory study completed by WES. This correlation was developed for cores with a length to diameter ratio of 2:1. Most cores collected from pavements do not have a 2:1 ratio of length to diameter; therefore, a correction factor is applied to adjust to the standard length. This test procedure has been more accurate and produced less scatter than split tensile testing. However, when cores do not produce reasonable results they are tested using conventional split tensile procedures. When this is required, PCC cores are tested for strength by tensile splitting in accordance with standard practices. The core tensile strengths are then converted to flexural strengths using an empirically developed relationship (Reference 7).

The AFCESA soil laboratory is capable of USCS soil classification, frost code classification, compaction testing, and laboratory CBR testing.

NEW TECHNOLOGIES

The APE team is continually working to integrate new technologies into the pavement evaluation program. One current initiative is to integrate collection and use of GPS/GIS data into the pavement evaluation process. GPS/GIS data will be used to geospatially reference core locations, HWD drops, and DCP/ECP test locations. This initiative will mesh with the current Air Force development of GeoBase, the georeferencing of all USAF facilities. A second intiative is combining all Pavement-Transportation Computer-Assisted Structural Evaluation (PCASE) software with MicroPAVER to produce a single pavement management software system. Finally, AFCESA is evaluating the role of Ground Penetrating Radar (GPR) in the future of the USAF Airfield Pavement Evaluation Program.

CONCLUSION

Since its inception in 1970, the USAF Airfield Pavement Evaluation Program has adapted to meet the needs of an ever-changing Air Force. Specifically, an Air Force with an expanding global presence but a dwindling manpower supply dictates a continual search for new technology that will help the APE team fulfill its mission. More reliable, more efficient, and less intrusive pavement evaluation technology and techniques is always the goal of the APE team.

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